Evaluation of Uncertainties in decay constants of "short-lived" radionuclides: a meta-analysis approach

P. Boehnke[1] and R. C. J. Steele[1]. [1]Department of Earth, Planetary, and Space Sciences, University of California, Los Angeles, USA. E-mail: pboehnke@gmail.com.

Introduction: Radionuclides with short half-lives on a geologic scale (e.g., ^{26}Al) have given us insights into the formation of our solar systems that were otherwise unattainable. These advances include the discovery of nucleosynthetic input into the solar system within 10^7 or 10^8 years of formation[1] or a ~5Ma formation interval between CAI's and chondrules[2]. Additionally, due to their short half-lives, short-lived radionuclides hold the promise for a high-precision time-scale of early solar system events if the assumption of homogeneity is met. However, to date numerous authors have shown discrepancies between different short-lived chronometers and long-lived clocks[3,4]. These discrepancies have multiple plausible causes including analytical issues, thermal effects/metamorphism, genuine heterogeneity, and the value of the half-life that is used.

Results and Discussion: In our work we examine experimental studies measuring the half-lives of various cosmochemically relevant systems (e.g., ^{10}Be, ^{26}Al, ^{41}Ca, ^{53}Mn, ^{60}Fe, ^{92}Nb, ^{129}I, ^{146}Sm, ^{182}Hf, and ^{244}Pu) through a meta-analysis[5]. We first performed a systematic review of the published experimental determinations, and studies that met our criteria (e.g., measured the purity of their samples, the isotopic ratios and included a description of the analytical considerations) were then combined through a random effects model.

We show that the quality and agreement of the literature varies from system to system. For example, ^{10}Be has four studies which met our criteria for inclusion and the agreement between them was fairly good. On the other hand for ^{129}I no study met our criteria for inclusion. Additionally, recently published studies have suggested that the half-lives for both ^{60}Fe[6] and ^{146}Sm[7] need considerable revision.

We can provide recommended half-lives for various systems (e.g., ^{26}Al) but for others conclude that the value is only semi-quantitatively known (e.g., ^{53}Mn). A further consideration is the inclusion of appropriate uncertainties on half-life measurements when dating early solar system events. For example, in the ^{26}Al system, using our new estimate of the half-life, the propagated uncertainties in the age of the Efremovka E-60 CAI[8] to D'Orbigny[3,4], would increase from ~80ka to ~260ka. With the uncertainties present in the decay constant literature, it is necessary for further experimental work to be undertaken before a robust short-lived chronology can be developed, or for inter-radionuclide heterogeneities to be uncovered.

References: [1] Reynolds J. H. 1960. *Physical Review Letters 4:* 8–10 (1960). [2] Davis A. M. and McKeegan K. D. 2014. *Treatise on Geochemistry:* 361–395. [3] Amelin Y. 2008. *Geochimica Cosmochimica Acta 72:* 221–232. [4] Spivak-Birndorf L. et al. 2009. *Geochimica Cosmochimica Acta 73:* 5202–5211. [5] Boehnke P. and Harrison T. M. 2014. *International Geology Review 56:* 905-914. [6] Rugel G. *et al.* 2009. *Physical Review Letters 103:* 072502. [7] Kinoshita N. *et al.* 2012. *Science 335:*1614–1617. [8] Amelin], Y. et al. 2002. *Science 297:* 1678–1683.